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RECIRCULATING FARM IRRIGATION SYSTEMS [a]

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SYNOPSIS

A survey of systems for recirculating runoff water from irrigation in southern Idaho shows little evidence of formal system design. Systems were constructed to handle approximately 20 percent of the volume of irrigation water. Costs of the systems vary with the type of installation. Sequence, reservoir, and cycling sump systems each has certain advantages. Recirculating systems are not effective unless the water is applied to a different area than that which is contributing runoff. Recirculating irrigation systems can raise water application efficiencies to 80 percent.

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INTRODUCTION

Concepts of efficient irrigation are continually changing. They are modified by economics, the utilization of labor, materials, and capital. The farmer, in order to gain a maximum economic return from his farming operation, may use water as a substitute for labor when water is relatively abundant and inexpensive.

Many irrigators consider an efficient irrigation one in which all the water has been absorbed by the soil on the field. Current studies show that where cutback streams are not used, best irrigation efficiency will result when a specified amount of runoff occurs. Irrigation can be accomplished with no runoff and a minimum of deep percolation loss with well designed border irrigation systems. In most furrow systems and in poorly designed or operated border systems, irrigation with little or no runoff will result in large deep percolation losses.

When deciding between the desirability of having either deep percolation loss or runoff, several reasons become apparent as to the desirability of choosing runoff: (1) runoff water can usually be recovered; (2) it does not contribute to groundwater, drainage, and salinization problems; and (3) it is not wasteful of fertilizer materials through leaching. Runoff should be limited so that soil erosion does not occur. In addition, it appears that the present trend toward more mechanization and automation of surface irrigation may introduce a need for controlled amounts of runoff.

Surface runoff suggests an obvious recoverable addition to the farm irrigation water supply. As a result, in recent years there has been an upsurge in interest in recirculating irrigation systems and pumping systems for recirculating runoff and waste water from irrigated fields are becoming an important part of economical irrigation. Little previous work has been reported on the design of recirculating irrigation systems. The relationship of pump and sump size to the contributing area and possible runoff has not been determined. The functional requirements - what, why, and how much each part of the system is expected to do have not been investigated.

Some general information is available on sump design and storage requirements for given pumping rates. Little thought has apparently been given to the potential quantity and rate of runoff from irrigated fields under varying conditions of water supply, soils, crops, and topography, or how recirculated flows may be integrated in the supply system. Some individual return flow systems are described in the literature but there is no indication that any engineering data are available for design. Typically, a sump is dug in an appropriate spot and a pump and return line installed. It is not known whether the runoff is measured beforehand.

SURVEY RESULTS

A survey was conducted during the fall of 1964 and spring of 1965 to obtain information about systems in the Eden-Hazelton-Murtaugh area and the Oakley Valley area of southern Idaho. An attempt was made to obtain information about soils, topography, contributing area, sump area, pump and controls, pipelines and costs. A total of 66 recirculating irrigation systems pumping entirely from runoff were located in these areas. The data obtained from the survey are summarized in Table 1. The area to which the recirculated water was applied varied from 40 to 160 acres and averaged approximately 70 acres. The area contributing runoff varied from 120 acres to 500 acres and averaged about 240 acres. This does not mean that all of the contributing area or the area using recirculated water was irrigated at one time.

Few recirculating systems were being operated when the survey was conducted and inflow and pumping rates were not available. Few of the irrigators knew the rate at which they were pumping water. In general most systems appeared to be pumping about 1.5 cfs., with a range of 0.5 to 2.00 cfs. Most owners consulted did not think it economically feasible to pump less than 1 cfs. There were no measuring devices to be seen at any of the recirculating installations. The only measuring devices in the area were those at the canal turnouts on farms obtaining water from a canal system. All of the water supplies in the Oakley area were from wells. The steeper topography in the Eden-Hazelton-Murtaugh area is reflected by the greater length of pipelines and results in increased installation costs.

In areas where the slope of the contributing area was greater than 0.5 percent, silt problems were more in evidence than on systems having contributing areas with flatter slopes. In some systems it appeared that the annual cost of silt disposal might be as much as annual power costs for the pumping operation.

Table 1. —Summary of recirculating surface irrigation systems, southern Idaho, 1964-1965

	Eden, Hazelton and Murtaugh		Oakley	
	w/ pipe [1/]	w/o pipe [2/]	w/ pipe	w/o pipe
Pump installations, no.	16	6	26	20
Area irrigated, acres, avg.	61.0	75.0	75.0	64.0
Contributing area, ac., avg.	261	320	250	226
Total pumping head, ft. avg.	38.5	9.5	23.0	12.0
Pipeline length, ft. avg.	1485	< 100	777	< 100
Reservoir storage, ac.-ft., avg.	1.9	1.8	2.3	2.3
Total cost per installation, avg.	$3746.00	$2375.00	$2920.00	$1516.00
Cost per acre, avg.	$ 61.40	$ 31.60	$ 39.00	$ 23.70
Cost per HP per acre, avg.	$ 6.33	$ 3.60	$ 3.48	$ 2.60
Pump, turbine type, no.	11	5	2	2
Pump, paddle wheel type, no.	5	0	23	18
Pump Horsepower, avg.	9.7	8.8	11.2	9.1

1/ With pipeline for returning water to distribution system longer than 100 feet.

2/ With pipeline for returning water to distribution system less than 100 feet long.

Two types of pumps were used on the recirculating systems. One was a paddle wheel centrifugal pump and the other was a short coupled vertical turbine pump. Forty-six of the installations used the paddle wheel centrifugal pump. The remaining 20 were short coupled vertical turbine centrifugals. The paddle wheel type generally has lower potential efficiency but has the advantage of being able to pump some trash. The vertical turbine type pump requires trash screening and continuous bowl submergence while pumping, but is more efficient at higher heads.

Many of the owners thought that enough water should be stored to irrigate a separate area using a 24 hour irrigation period. Accordingly, collection reservoir size ranged from 0.6 ac.-ft. to as high as 8 ac.-ft. with the average volume being about 2.0 ac.-ft.

Most installations appear to have been developed, not designed. This was evidenced at several installations by the spare pulleys found lying around, indicating that the farmer changed the pump speed to match his particular runoff conditions.

Pump stands in reservoirs were generally made by stacking two four-foot lengths of 30- or 36-inch diameter concrete pipe on end. An inlet hole was cut on the side of the bottom piece of pipe creating an underwater intake that provided some escape from pumping trash. Further reduction of trash intake could probably be obtained by allowing a larger radius of inlet or by providing several radial pipe inlets to the pump stand creating several lower velocity intake points.

EXPECTED RUNOFF

A recent study on farms in the Rupert, Idaho[3] area showed an average farm runoff of 18.5 percent of the total water delivered to the farm. Losses by deep percolation were computed to be of approximately the same magnitude.

Davis[4], from surveys made in California, reports that farms having an area size of 160 acres produced runoff of 10 to 20 percent of the water used for irrigation.

A theoretical study was conducted by the authors to determine the volumes of expected runoff from fields using typical irrigation stream advance and infiltration data. Runoff, deep percolation and moisture stored in the root zone were computed for various combinations of length of run and desired depth of irrigation at the lower end of the field. Infiltration was represented by the expression:

$$I = Kt^N \quad \ldots \quad (1)$$

where I is the cumulative infiltration, t is time and K and N are values characteristic of the soil. The stream advance was given by the equation:

$$t = A(1 - e^{Cx}) \quad \ldots \quad (2)$$

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[3] Tyler, C. L., G. L. Corey, and L. B. Swarner, "Evaluating Water Use on a New Irrigation Project," Idaho Agricultural Experiment Station Research Bulletin No. 62, 1964.

[4] Davis, John R., "Design of Irrigation Tailwater Systems," TRANSACTIONS of the ASAE, Vol. 7, No. 3, 1964, pp. 336-338.

where t is time, A and C are constants for the particular conditions, x is the advance distance, and e is the natural logrithm base.

Results are presented for K, N, A and C values of 0.5, 0.5, –2.0, and 0.002, respectively, and a 1320 foot length of run, Figure 1. The values shown by the curves are computed at the total time required to apply the desired depth of irrigation water at the lower end of the field. For any given time the runoff plus the absorbed water will equal the water stored in the root zone. Presented in this manner, as a percent of the total applied water, the water stored in the root zone is the irrigation application efficiency.

The curves in Figure 1 are easily used. For example, if a 12 inch irrigation is to be applied, runoff will begin at approximately 5 percent of total time and will amount to about 50 percent of the applied water. The percent of total water absorbed by the soil will be approximately equal to that stored in the soil, 50 percent, since deep percolation will be negligible. Similarly, if a 2 inch irrigation is to be applied, runoff will begin at about 60 percent of the total time of irrigation and will be approximately 10 percent of the applied water. Approximately 90 percent of the water applied will be absorbed by the soil, about 63 percent would be stored in the root zone and about 27 percent lost to deep percolation.

For this particular set of conditions, maximum water application efficiency is obtained with a 3.5 inch depth of irrigation and a corresponding runoff of about 20 percent of the total applied water. If the

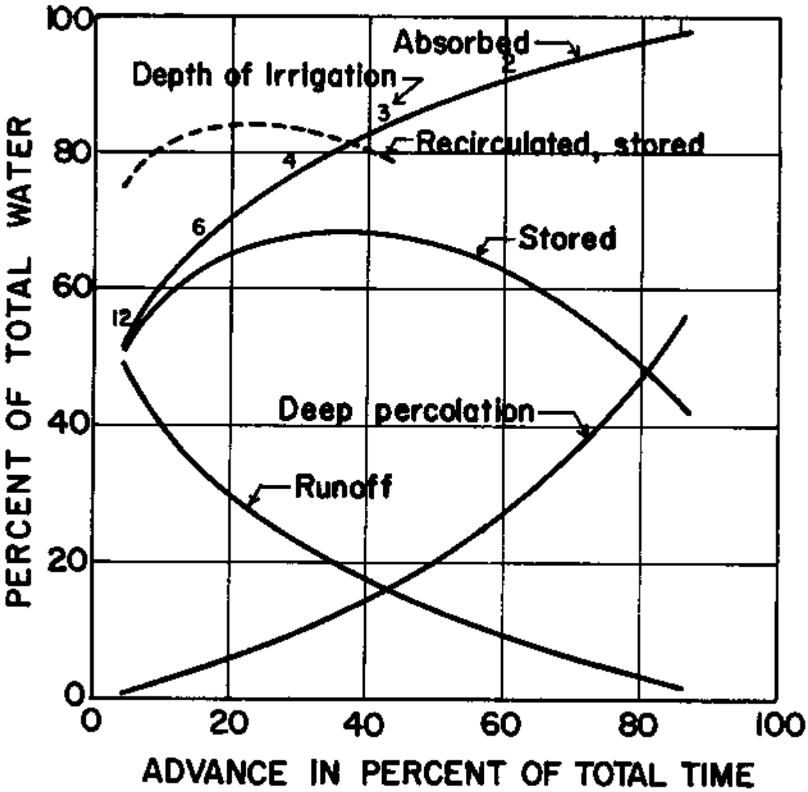

Figure 1. Irrigation Water Disposition Curves

runoff from the field is recirculated and reapplied at the same efficiency as the original irrigation, the application efficiency can be increased approximately 15 percent. For typical situations application efficiencies of 60 to 70 percent are attainable when runoff is approximately 20 percent. Recirculating the runoff will raise the application efficiency over 80 percent. Maximum application efficiencies with recirculation of runoff are obtained with about 30 percent runoff from the original stream. This applies to systems having average infiltration rates and neither fast or slow advance rates, i. e., advance time/total time ratios between 1 and 9.

SYSTEM MANAGEMENT

Recirculating systems can generally be classified into three types: (1) sequence systems, (2) reservoir systems, and (3) cycling sump systems. Depending on the individual situation, one or more types of system may be applicable.

Sequence systems are the simplest. They may consist only of a means of collecting runoff at the end of a field and applying it to an adjacent field. Under ideal conditions this may not even require a pump. Several sequence systems were found in the previously mentioned survey. These systems generally had only a small sump, a pump, and a short length of pipe. The runoff water collected from one field was pumped across the road and applied to the next field, which was at a slightly lower elevation. With proper planning and some land leveling, it may be possible to install sequence systems which do not require a pump. These should have enough elevation difference between fields to allow runoff water to be applied to the lower field without having to be pumped.

Reservoir systems were the most common found in the survey. For this method, a reservoir sufficiently large to hold all the runoff which may occur in a 24 hour or longer period is required. The recovered water may then be pumped as a fully independent supply to some other part of the farm or may be combined with the original water supply.

Cycling-sump systems are usually designed using criteria similar to those for pump outlet drainage systems. They have a small sump and a float system which controls the pump operation. Shahroody and Davis [6/] give specific recommendations for the hydraulic design of sumps for vertical turbine pumps. Sump size, pumping rates and cycling frequency were discussed by Davis [4/] in an earlier article.

Management of the recirculated water in the irrigation system is a problem that has not received sufficient attention. Unless some consideration is given to this problem, the desired increase in efficiency may not be obtained. Care of small streams may be an inefficient use of labor. The water may be largely wasted if it is not carefully applied. Combining recirculated water with a primary flow from the farm supply may result in better efficiencies of labor and water use. Where the runoff water is recirculated into an irrigation system the area being irrigated will have to be increased.

[6/] Shahroody, Ali M., and John R. Davis, "Efficiency of Pumping From Small Circular Sump," JOURNAL OF THE IRRIGATION AND DRAINAGE DIVISION, ASCE, Vol. 90, No. IR 1, Proc. Paper 3817, March 1964, pp. 1-8.

In the sequence use system water is applied to a small portion of an adjacent field. If a storage reservoir is included in the recirculating system, fewer problems will be encountered as the pumping rate from the reservoir will be constant and the flow can be treated as a separate full irrigation supply. It is the equivalent of having an additional irrigation stream.

The most difficult management problem exists when cycling-sump systems are used. Analysis of the problem of integrating recirculated runoff into the original supply shows that the cycling-sump is not a feasible idea. All that is accomplished if the water is added to the area already being irrigated is storage of the runoff water on the surface of land. This only prevents it from ending up in the borrow pit at the expense of pumping costs. The runoff water from any recirculating system must be applied to another or additional area in order to actually make use of it.

HYDROLOGY

The hydrology of the collection area should not be ignored. If the surface water from the entire farm is channeled by waste ditch into the holding reservoir for recirculation, there is a possibility of damage due to runoff from rainfall or melting snow. During irrigation, runoff is usually received from only the area being irrigated and the reservoir and pumping system are designed for this condition. If rainfall occurs, a small amount of runoff from the larger farm area may be enough to overtop the reservoir. Therefore, overflow or spillway capacity may have to be built into the system if this is a possibility. Such damage occurred during the 1964-65 winter in some of the Idaho installations surveyed. Rains falling on a snow cover produced a large amount of runoff at a time when the systems were not attended. As a result several reservoirs had major washed-out sections.

SILTATION

Basic soil conservation practices should not be ignored in the installation of recirculation systems. Irrigation systems should be designed so that a minimum of silt is produced from the contributing fields. In general the systems surveyed in Idaho did not conform to this recommendation. Some of the reservoirs accumulated so much silt that they had to be cleaned annually. The cost of silt removal in some systems was estimated to be approximately as much as the pumping costs for recirculation of water.

While not practiced in all of the systems surveyed, the silt removed from the reservoir can be redistributed on the contributing field. This topsoil can be used to reduce the slope of the field or to fill in depressions, swales, etc. which contribute to uneven distribution of irrigation water.

CONCLUSIONS

Analysis of the status of design of recirculating irrigation systems shows that very little work has been done to determine design criteria or functional requirements of such systems. It has been shown that the water application efficiency of typical surface irrigation systems can be improved by about 15 percent if the runoff water is recirculated and used at the same efficiency on additional land.

Estimates of the volume of runoff expected for various field conditions have been obtained from general field observations. Reservoir size is usually flexible but pumping rates will depend on the method of use of the recirculated water. Sequence and reservoir recirculating systems will give a continuous flow which can be used independently or combined with another water supply. If the recirculated water is combined with the original supply the irrigated area must be expanded to obtain any benefit. The cycling-sump system can be used effectively only where the water can be applied to an area which is separated from the area producing the runoff being recirculated.

A survey of existing recirculating systems in southern Idaho showed a definite lack of design criteria and engineering design data. These systems also show lack of basic soil conservation and hydrologic design considerations. Two-thirds of these installations had pumping plant installations which could be improved by better equipment and better plant design.